

What is claimed is:

1. A method of controlling a direct injection internal combustion engine, said method comprising
 - 5 a. calculating output data from system data, said system data comprising
 - i. an injector geometry defined by a fuel injector in fluid communication with a combustion chamber of said engine,
 - ii. an engine geometry defined by said engine,
 - 10 iii. an engine operating command based on a desired engine output,
 - iv. an initial injector command,
 - v. an engine speed,said engine operating command being indicative of a commanded torque for said engine, said output data comprising
 - 15 i. an engine out value indicative of a brake torque delivered by said engine, and
 - ii. an output control parameter indicative of a cylinder pressure value,
 - 20 b. when said output data does not satisfy a predetermined relationship, determining a subsequent injector command and recalculating said output data with said subsequent injector command, where said predetermined relationship compares said output data and said engine operating command and a demanded control parameter, said demanded control parameter being indicative of a maximum cylinder pressure value,
 - 25 c. when said output data satisfies said predetermined relationship, commanding said injector to provide fuel to said combustion chamber according to a last injector command.
- 30 2. The method of claim 1 wherein said system data further comprises

an ambient temperature and an ambient pressure.

3. The method of claim 2 wherein said ambient temperature and said ambient pressure are measured prior to calculating said output data.
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4. The method of claim 1 wherein said engine speed is measured prior to calculating said output data.
- 10 5. The method of claim 2 wherein said engine operating command is converted to said commanded torque based on an operator selected pedal position.
6. The method of claim 1 wherein said demanded control parameter is determined from said engine operating command.
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7. The method of claim 1 wherein said output control parameter is indicative of calculated emissions and said demanded control parameter is indicative of a demanded emission.
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8. The method of claim 7 wherein said calculated emissions and said demanded emissions are indicative of at least one of a NO_x concentration and a particulate matter concentration.
- 25 9. The method of claim 1 wherein said predetermined relationship further comprises comparing said output data with at least one previously calculated fuel consumption determined from said system data using said initial injector command or said subsequent injector command, said output data further comprising said
30 calculated fuel consumption.

10. The method of claim 9 wherein said predetermined relationship comprises said calculated fuel consumption being less than said at least one previously calculated fuel consumption.
- 5 11. The method of any one of claims 1, 2 and 9 wherein
- a. said initial injector command comprises a commanded initial start of injection, a commanded initial pulse width and a commanded initial rail pressure,
- 10 b. said subsequent injector command comprises a commanded subsequent start of injection, a commanded subsequent pulse width and a commanded subsequent rail pressure, and,
- c. said last injector command comprises a commanded last start of injection, a commanded last pulse width and a commanded last rail pressure.
- 15 12. The method of claim 1 wherein said engine further comprises a variable geometry turbine and said system data further comprises an initial variable geometry turbine position, further comprising
- 20 a. when said output data does not satisfy said predetermined relationship, determining a subsequent variable geometry turbine position, with said subsequent variable geometry turbine position and said subsequent injector command, recalculating said output data
- b. when said output data satisfies said predetermined relationship,
- 25 commanding said variable geometry turbine according to a last variable geometry turbine position.
13. The method of claim 1, wherein said engine further comprises an EGR system and said system data further comprises an initial
- 30 effective EGR valve flow area, further comprising,
- a. when said output data does not satisfy said predetermined

- relationship, determining a subsequent effective EGR valve flow area, with said subsequent effective EGR valve flow area and said subsequent injector command, recalculating said output data,
- 5 b. when said output data satisfies said predetermined relationship, commanding said EGR system according to a last effective EGR valve flow area.
14. The method of claim 1 wherein said output data is calculated using
- 10 a. an injector module for calculating IM/CM data and IM/ECM data from an estimated initial cylinder pressure and IM system data, said IM system data being a subset of said system data,
- 15 b. a combustion module for calculating CM/ECM data from an estimated initial intake flow rate, said IM/CM data and CM system data, said CM system data being a subset of said system data,
- 20 c. an engine cycle module for calculating said output data from said CM/ECM data, said IM/ECM data and said ECM system data, said ECM system data being a subset of said system data,
- 25 wherein, prior to calculating said output data, a small loop between said combustion model and said engine cycle module is used to provide a converged intake flow rate and, a big loop between said injection module, said combustion module and said engine cycle module is used to provide a converged cylinder pressure, said
- 30 converged cylinder pressure used to provide said cylinder pressure value.
15. The method of claim 14 wherein said IM/CM data comprises an IM rate of injection and an IM start of injection.
16. The method of claim 14 wherein said IM/ECM data comprises an

IM fuel flow and an IM start of injection.

17. The method of claim 14 wherein said CM/ECM data comprises a
CM heat release rate and a CM start of combustion.
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18. The method of claim 14 wherein said output data is further
calculated using an emissions module for calculating emissions
data from ECM/EM data, said IM/ECM data and said system data,
said output control parameter being indicative of calculated
10 emissions and said demanded control parameter being indicative of
a demanded emission.
19. The method of claim 14 wherein said IM system data comprises an
ambient pressure, said injector geometry, said engine speed and
15 said injector command.
20. The method of claim 14 wherein said CM system data comprises
said engine speed and said engine geometry.
- 20 21. The method of claim 14 wherein said ECM system data comprises
an ambient pressure, an ambient temperature, said engine geometry
and said engine speed.
22. The method of any one of claims 1 through 21 wherein said engine
25 is fuelled, at least partially, by a gaseous fuel.
23. The method of claim 22 wherein said gaseous fuel is natural gas.
24. The method of claim 22 wherein said gaseous fuel comprises at
30 least one of methane, hydrogen, ethane and propane.

25. The method of claim 22 wherein said gaseous fuel is hydrogen.
26. A method of predicting output data generated by a direct injection internal combustion engine, said output data comprising at least one of engine torque, fuel consumption, power and cylinder pressure, said method comprising
- 5 a. selecting system data, said system data comprising:
- i. an injector geometry indicative of a selected fuel injector,
- 10 ii. an engine geometry indicative of said engine,
- iii. an engine speed,
- iv. an injector command,
- b. estimating initial data, said initial data comprising an initial cylinder pressure and an initial intake flow,
- 15 c. calculating said output data using said system data and a converged cylinder pressure and a converged intake flow wherein said initial data used to:
- i. provide said converged cylinder pressure from said initial cylinder pressure,
- 20 ii. provide said converged intake flow from said initial intake flow.
27. The method of claim 26 wherein said system data further comprises at least one of an ambient pressure and an ambient temperature.
- 25 28. The method of claim 26 wherein said output data further comprises at least one of NO_x concentration and particulate matter concentration.
- 30 29. The method of claim 26 wherein said injector command comprises

a commanded rail pressure, a commanded start of injection and a commanded pulse width.

30. The method of claim 26 wherein said system data further
5 comprises at least one of a commanded variable geometry turbine position and an effective EGR valve flow area, wherein if an effective EGR valve flow area is included, said system data further comprises an initial EGR flow.
- 10 31. The method of claim 27 wherein said output data is calculated using
- a. an injector module for calculating IM/CM data and IM/ECM data from said initial cylinder pressure and IM system data, said IM system data being a subset of said system data,
 - 15 b. a combustion module for calculating CM/ECM data from said initial intake flow, said IM/CM data and CM system data, said CM system data being a subset of said system data,
 - c. an engine cycle module for calculating said output data from said CM/ECM data, said IM/ECM data and ECM system data, said ECM system data being a subset of said system data,
- 20 wherein a small loop between said combustion module and said engine cycle module is used to converge to said converged intake flow and, a big loop between said injection module, said combustion module and said engine cycle module is used to
- 25 converge to said converged cylinder pressure.
32. The method of claim 31 wherein said output data is further calculated using an emissions module for calculating emissions data from ECM/EM data, said IM/ECM data and EM system data, said EM system data being a subset of said system data, said
30 output data further comprising said emissions data.

33. The method of claim 32 wherein said emissions data is indicative of at least one of a NO_x concentration and a particulate matter concentration.
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34. The method of claim 31 wherein said ECM/EM data comprises said converged cylinder pressure, said converged intake flow, an intake valve closing time cylinder pressure and an intake valve closing time cylinder temperature, said intake valve closing time cylinder pressure and said intake valve closing time cylinder temperature provided by said engine cycle module.
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35. The method of claim 31 wherein said IM/CM data comprises an IM rate of injection and an IM start of injection.
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36. The method of claim 31 wherein said IM/ECM data comprises an IM fuel flow and an IM start of injection.
37. The method of claim 31 wherein said CM/ECM data comprises a CM heat release rate and a CM start of combustion.
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38. The method of claim 31 wherein said IM system data comprises said injector geometry, said engine speed, said ambient pressure and said injector command.
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39. The method of claim 31 wherein said CM system data comprises said engine speed and said engine geometry.
40. The method of claim 31 wherein said ECM system data comprises said engine geometry, said ambient pressure, said ambient temperature and said engine speed.
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41. The method of any one of claims 26 through 40 wherein said engine is at least partially fuelled by a gaseous fuel.
- 5 42. The method of claim 41 wherein said gaseous fuel is natural gas.
43. The method of claim 41 wherein said gaseous fuel comprises at least one of methane, hydrogen, ethane and propane.
- 10 44. The method of claim 41 wherein said gaseous fuel is hydrogen.
45. A method of controlling a direct injection internal combustion engine, said method comprising
- a. calculating output data from system data, said system data
- 15 comprising
- i. an injector geometry defined by a fuel injector in fluid communication with a combustion chamber of said engine,
- ii. an engine geometry defined by said engine,
- iii. an engine operating command based on a desired
- 20 engine output,
- iv. an initial injector command,
- v. an engine speed,
- said engine operating command being indicative of a commanded torque for said engine, said output data comprising
- 25 i. an engine condition value indicative of a condition within said engine,
- ii. an engine out value indicative of a brake torque delivered by said engine, and
- iii. an output control parameter indicative of a cylinder
- 30 pressure value,
- b. when said output data does not satisfy a predetermined

- 5 relationship, determining a subsequent injector command and recalculating said output data with said subsequent injector command, where said predetermined relationship compares said output data and said engine operating command and a demanded control parameter, said demanded control parameter being indicative of a maximum cylinder pressure value,
- c. when said output data satisfies said predetermined relationship, comparing said engine condition value to a sensor reading to determine accuracy of said sensor reading.

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46. The method of claim 45 wherein said engine condition value comprises in-cylinder pressure and said sensor reading comprises an in-cylinder pressure sensor reading.